REFRIGERATION STUDY FOR DOMESTIC APPLICATION

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SUPERVISOR'S DECLARATION

We hereby declare that we have checked this project and in our opinion this project is satisfactory in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering

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STUDENT'S DECLARATION

I hereby declare that the work in this thesis is my own except for quotations and summaries which have been duly acknowledged. The thesis has not been accepted for any degree and is not concurrently submitted for award of other degree.

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To my beloved father and mother,

Mr Wan Ramli bin Wan Abdul Rahman
Mdm Jariah binti Mohamad

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ABSTRACT

Refrigeration, cooling, and heating processes are important in a variety of everyday situations, including the air conditioning and heating of buildings, and in a treatment, transportation, and preservation of foods and beverages. Refrigeration also finds large scale industrial application, for example, in the manufacture of ice and the dehydration of gases. This paper gives an understanding of refrigeration study for domestic application. By learning and understanding the basic vapour-compression refrigeration systems, the performance of refrigeration system expected can be determined using refrigerator test rig. The literature study has been conducted by two important parameters in order to analyze performance of the refrigerator. These parameters are pressure and temperature. The literature study is crucial at the location of parameter on the test rig that will be develop. This paper also describes procedure to fabricate the test rig. Then, the refrigerator test rig will test in order to analyse the performance of the refrigerator test rig. The performance of the refrigerator test rig analyse by the using the actual pressure-enthalpy diagram of actual refrigeration cycle and by using the equation. This study may help the audience to analyze the actual performance of the refrigerator performance for domestic application.

ABSTRAK

Penyejukan, pendinginana dan pemanasan adalah proses yang penting dalam pelbagai situasi setiap hari, termasuklah penghawa dingin dan pemanasan bangunan dan dalam rawatan, pengangkutan dan pengekalan kualiti makanan dan minuman. Penyejukan digunakan secara meluas dalam aplikasi perindustrian, contohnya dalam pembuatan ais dan dehidrasi gas. Kertas kerja ini memberi pemahaman dalam kajian untuk penggunaan domestik. Melalui pembelajaran dan pemahaman asas kemampatan wap sistem penyejukan, kecekapan sistem penyejukan yang dijangka boleh ditentukan menggunakan pegendali ujian peti ais. Kajian kesusasteraan telah dibimbing oleh dua parameter penting dalam mengkaji kecekapan sesbuah peti ais. Parameter-parameter tersebut adalah tekanan dan suhu. Kajian kesusasteraan genting di lokasi parameter pada pengendali ujian peti ais yang akan dibuat. Kertas kerja ini juga menghuraikan prosedur untuk membuat the pegendali ujian. Kemudian, pengendali ujian peti ais akan diuji untuk analisis kecekapan pengendali ujian peti ais tersebut. Kecekapan pengendali ujian peti sejuk dianalisis menggunakan gambar rajah tekanan-entalpi sebenar bagi putaran penyejukan dan menggunakan persamaan. Kajian ini dapat membantu masyarakat untuk analisis kecekapan sebenar bagi sesebuah peti ais untuk aplikasi domestik.

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LIST OF SYMBOLS

$\dot{m}$	Mass flow rate
$\dot{Q}_L$	Refrigeration capacity
$\dot{Q}_H$	Heating capacity
Q_H	Heat rejection in a condenser
Q_L	Refrigerant effect
P	Pressure
V	Volume
R	Gas constant value
T	Temperature
P	Compressor power
W	Work done
h	Enthalpy value
W_{comp}	Work of compressor
V	Voltage

LIST OF ABBREVIATIONS

ANSI	American National Standards Institute
ARI	Air Conditioning and Refrigeration Institute
ASHRAE	American Society of Heating, Refrigeration, Air Conditioning Engineers
COP	Coefficient of Performance
UMP	Universiti Malaysia Pahang

CHAPTER 1

INTRODUCTION

1.1 The Domestic Refrigerator

Refrigeration is widely used in variety of thermal engineering applications. Refrigeration is defined as the process of removal of heat from an enclosed space, or from a substance, and rejecting it elsewhere for the primary purpose of lowering the temperature of the enclosed space or substance and then maintaining that lower temperature. The refrigeration system actually based on a vapor-compression cycle which consisting four main components; a compressor, a condenser, a capillary tube or expansion valve and an evaporator. The working fluid that used in the refrigeration system is R-134a. The first patent of a vapor-compression refrigeration system was obtained by American inventor named Jacob Perkins in 1834.

The cycle of vapor-compression of refrigeration start when the refrigerant enters the compressor at high pressure of superheated vapor and it's compressed isentropically to the condenser pressure. Then, the refrigerant enters the condenser as superheated vapor and leaves as saturated liquid as a result of heat rejecting to the surroundings. The saturated liquid refrigerant is throttled to the evaporator pressure by passing it through an expansion valve or capillary tube. During this process, the temperature of the refrigerant drops below the temperature of the refrigerate space. Then, the refrigerant enters the evaporator as a low-quality saturated mixture, and it completely evaporates by absorbing heat from the refrigerated space. The cycle is complete as the refrigerant leaves the evaporator and re-enters the compressor.

This report gives an understanding of refrigeration study for domestic application. By learning and understanding the basic vapor-compression refrigeration systems, the performance of refrigeration system expected can be determined. The test rig will be develop in order to analyze the performance of refrigerator. The author has conducted literature study in identify parameter to analyze the refrigerator performance. The literature study is crucial at the location of parameter on the test rig that will be developed. Based on the literature study, a test rig is being developed according to the international standard for tropical climate such as ASHRAE, AHAM and ARI to generate the refrigerator performance.

1.2 Problem Statement

Nowadays, refrigeration system is important in a wide variety used for domestic application. However, the actual performance of the refrigerator still unknown. So, we need some research to analyze the actual performance of refrigerator.

1.3 Objective of Research

The main objective of this study is to develop experimental rig for refrigeration system and to determine the coefficient of performance (COP) of the refrigeration system.

1.4 Scope

The scopes of this study are:

1) Literature Study

   The literature study is focused how to identify the strategic and suitable locations of pressure and temperature measurement.

2) Thermodynamics analysis

By learning and understanding the basic vapor compression refrigeration systems, the performance of refrigeration system can be determined.

3) Test Rig development

In order to analyze performance of the refrigeration system, the test rig needs to be developed. There are two important of parameters in the rig development works which are location and measurement method of pressure and temperature.

4) Testing and analysis

Analyze the data by using P-*h* diagram and second law of thermodynamic to determine the coefficient of performance (COP) of the system.

CHAPTER 2

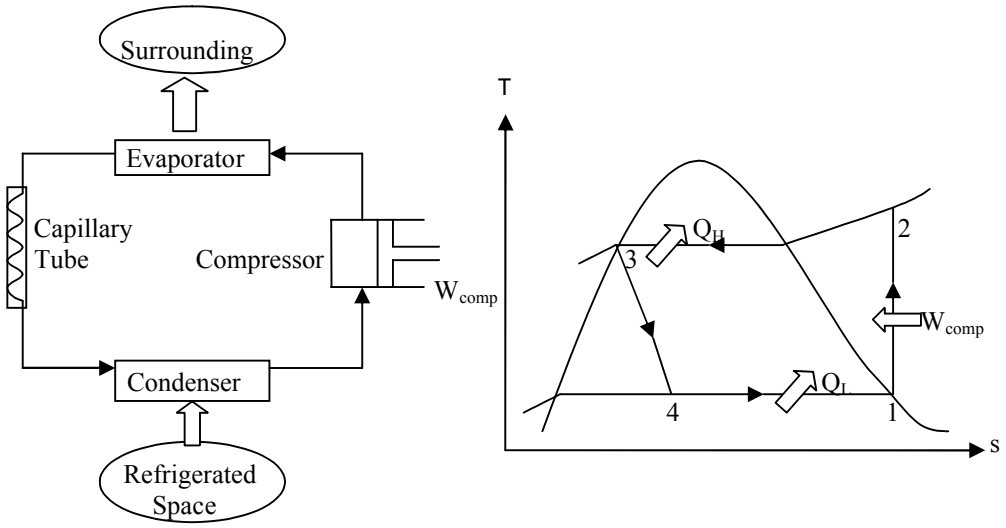
LITERATURE REVIEWS

2.1 Introduction

This chapter discusses the relevant reports on the description of refrigeration system, components that is installed in domestic refrigerators, measurement method and development reviews of refrigerator test rig. These reviews are important to analysis the performance of refrigerator system in domestic application.

2.2 Refrigeration System

Currently, there are many types of refrigeration system available in the market. Those refrigerators are classified according to their application. The most popular type of domestic refrigeration system is called refrigerator. Normally, this type of refrigeration system consists of two compartments which are cold and freeze compartments. The other types of refrigerator systems are freezer and cooler. The primary function of a refrigerator or freezer is to provide food storage space maintained at a low temperature for the preservation of food. Mechanical vapor compression cycle as well as the absorption cycle, are adopted for domestic refrigerators and freezer. Refrigeration is defined id the process of removal of heat from an enclosed space, or from substance, and rejecting it elsewhere for the primary purpose of lowering the temperature of the enclosed space or substance and then maintaining that lower temperature. The refrigeration system is that based on a vapor compression cycle which consisting four main components; a compressor, a condenser, a capillary tube or expansion valve and evaporator as shown in **Figure 2.1**



(a) Refrigerator plant (b) Ideal T-*s* diagram of refrigeration plant

Figure 2.1: Refrigeration cycle shown schematically and graphically

2.2.1 Components of Refrigerator System

There are several mechanical components required in a refrigerator system. Basically, there are four major components of vapor-compression refrigeration system. These components are compressor, condenser, capillary tube and evaporator [2].

2.2.1.1 Compressor

In a refrigeration cycle, the compressor has two main functions within the refrigeration cycle. The function of the compressor is to pump the refrigerant vapor from the evaporator so that the desired temperature and pressure of the system. The second function is to increase the pressure of the refrigerant vapor through the process of compression, and simultaneously increase the temperature of refrigerant vapor [3]. The pressure of the refrigerant vapor leaving the evaporator must be elevated (or the vapor has to be compressed) to the level of the condensing pressure, so that the refrigerant can be condensed into a liquid in the condenser and fed to the evaporator for the continuous refrigeration [4].

The most common compressor used in domestic refrigeration is reciprocating type. This type of compressor normally constructed with pistons, cylinders, valves, connecting rods and crankshaft as shown in **Figure 2.2**. The function of each main component that commonly used in reciprocating compressor are described below:

- Piston head – functions as the gas compressing "agent" by continuously reducing the cylinder volume
- Piston rings – functions as the sealant between the piston head, and the cylinder, to prevent gas leakage from the compression chamber
- Crank shaft – a shaft that enables the reciprocating motion of the piston
- Piston rod – the connecting piece between the piston head, and the crankshaft
- Spring loaded suction and discharge valves – separates low pressure side and high pressure side from the compression chamber. Enables positive displacement of gases, by correct opening and closing of the valves. Suction valve will open as the piston moves away from the valves, and discharge valve will open as the piston moves towards the valves. The valves will otherwise, be in closed position. The suction and discharge valve are usually a thin plate or reed that will open and close easily and quickly [3].
- Compressor's cylinder block – functions as the housing for the compressor parts

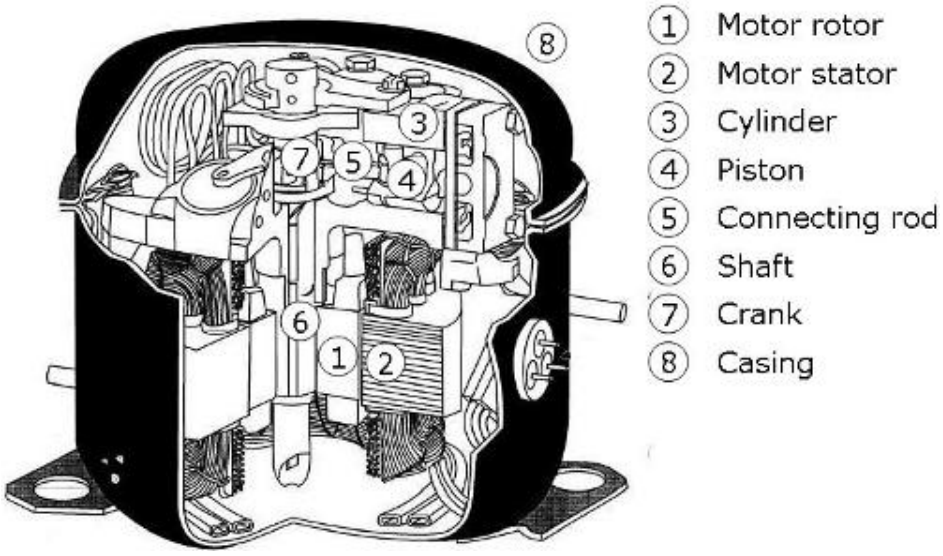


Figure 2.2: Cutaway of reciprocating compressor

2.2.1.2 Condenser

The heat extracted from the substance to be cooled by the refrigerant in the evaporator is rejected to the atmosphere through the condenser. There are several types of condensers that commonly used in refrigeration system. They are air-cooled, water-cooled, shell and tube, shell and coil, tube within a tube, and evaporative condensers [3]. However, most of domestic refrigerators are used evaporative condenser. The refrigerant is forced through the condenser. In order to remove as much heat as possible with the tubes arranged to provide maximize surface area. In the condenser, the temperature of the superheated vapor has to be brought down to its saturation temperature before condensed into a liquid. The first few tubes of the condenser 'desuperheat' the vapor. The pressure of the vapor, through superheated, remains the same, since the compressor is in operation. Once the vapor has been cooled, and brought down to the condensing temperature corresponding to the head pressure, the vapor begins to condense. During this process, the pressure and condensing temperature remain constant. In some water-cooled condensers, provision is made for sub-cooling the liquid from its saturation temperature by providing some water tubes at the bottom. The liquid can be sub-cooled

by the use of a liquid-suction heat exchanger also. The use of heat exchanger, obviously, will increase the superheat of the suction vapor. As too much superheating of the suction vapor will affect the compressor capacity, a heat exchanger is only used where absolutely essential [12].

2.2.1.3 Capillary Tube

The capillary tube is the simplest type of refrigerant flow control device and may be used in place of an expansion valve. The capillary tube is small-diameter tubes through which the refrigerant flows into the evaporator. These devices, which are widely used in small hermetic-type refrigeration system, reduce the condensing pressure to the evaporating pressure in a copper tube of small internal diameter, maintaining a constant evaporating pressure independently of the refrigeration load range. These tubes are used to transmit pressure from the sensing bulb of some temperature control device to the operating element. A capillary tube may also be constructed as a part of heat exchanger, particularly in household refrigerators [5, 6].

2.2.1.4 Evaporator

Evaporator can be considered the point of heat capture in refrigeration system and provides the cooling effect required for any particular application. In evaporator operation, the metering device changes the entering liquid to a dense fog of liquid droplets. During the same process, the high pressure liquid is lowered to what is called the evaporator pressure, or suction pressure. This pressure relates to the evaporator temperature. During evaporation, the refrigerant remains the same temperature (its saturation temperature) throughout the coil until all droplets of liquid are vaporized, or totally saturated.

Meanwhile, the refrigerant nears the end of evaporator part is in fully saturated vapor that can only absorb sensible heat; however it does not contribute much to the overall refrigeration performance.

2.2.2 Theory of Refrigeration Cycle

Commonly, refrigeration system works in a thermodynamic cycle which obeys Second Law of Thermodynamic which consists of four thermodynamic processes involving the working fluid, traversing four fluid states at low temperature, T_{low} and high temperature, T_{high} [1] and [2] as shown in **Figure 2.3**:

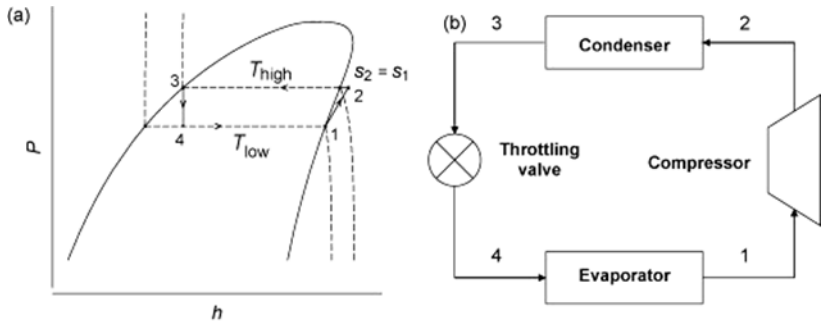


Figure 2.3: (a) Shows the process path on a pressure–enthalpy (*P*– *h*) diagram, and (b) shows a schematic diagram of the process equipment.

The cycle of refrigeration start when the refrigerant enters the compressor at low-pressure superheated vapor and is compressed isentropically to the condenser pressure. The refrigerant enters the condenser as superheated vapor and leaves as saturated liquid as a result of heat rejecting to the surroundings. The saturated liquid refrigerant is throttled to the evaporator pressure by passing it through an expansion valve or capillary tube. During this process, the temperature of the refrigerant drops below the temperature of the refrigerant space. Then, the refrigerant enters the evaporator as a low-quality saturated mixture, and it completely evaporates by absorbing heat from the refrigerated space. The cycle is complete as the refrigerant leaves the evaporator and re-enters the compressor.